AN INTEGRATED CARDIOLOGY PATIENT MANAGEMENT SYSTEM

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ABSTRACT

An integrated clinical database has been developed for all diagnostic cardiac services at Vancouver General Hospital. The system is installed on a Data General MV/10000 computer and utilizes the Flagship Application Generator from EPIC Systems Corp. Clinical information, as well as demographic and administrative data, is collected. The system features a custom menu for each user, whose selections provide direct access to the desired functional modules. The intention is to collect data from all the diagnostic areas of the Division of Cardiology, viz., Cardiac Ultrasound, Cardiac Catheterization Laboratory, Pacemaker Clinic and Electrocardiology (including 24 hour ambulatory EKGs and exercise testing). Automated links to the hospital's Admitting/Discharge/Transfer and Billing /Accounts Receivable systems have been implemented over the hospital's local area network. The system is used to produce routine reports of test results, patient billings, and departmental workload statistics. Inquiry functions permit the rapid location of patient records and produce an integrated profile of cardiology activity. In addition, selective searches of the data are available for research and/or other purposes.

INTRODUCTION

Vancouver General Hospital (VGH) is an 1100 bed teaching hospital located in Vancouver, British Columbia. The hospital also serves as the major tertiary referral centre for the province's population of approximately 2,000,000 people. In 1984, the hospital, through its Information Systems department, began the implementation of a distributed systems strategy based on a hospital-wide local area network (LAN) (Figure 1).

Approximately 50 different systems are in operation in the hospital including Cardiology, Laboratory, Radiology, Admitting/Discharge/Transfer (A/D/T), as well as financial and administrative systems. These systems are supported by a variety of technical environments: an IBM 4381 running VM, a number of Data General MV/10000s in the MIIS environment, a DEC PDP 11/70 using RSTS, as well as a number of PCs and other smaller systems. The LAN chosen was the Ungermann-Bass Net/One product, a baseband ethernet conforming to the IEEE 802.3 standards.

The Division of Cardiology accommodates 13 cardiologists and approximately 36 other staff within four

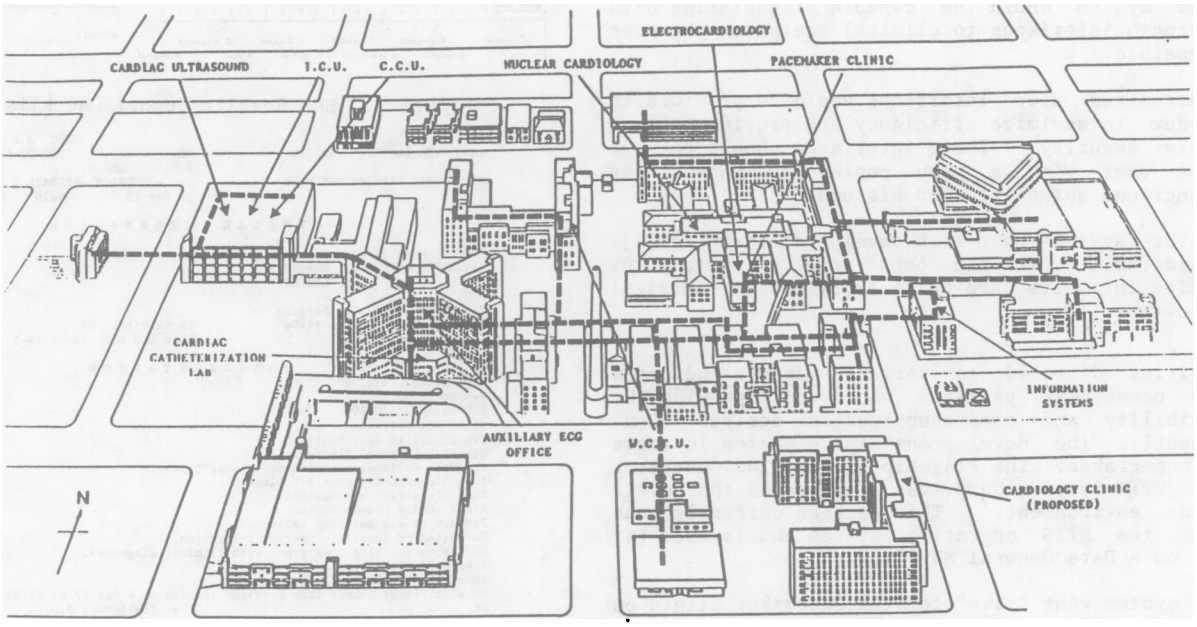

Figure 1. Vancouver General Hospital Schematic Geographical Layout

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functionally and physically distinct areas:

- Electrocardiology
- Pacemaker Clinic
- Cardiac Ultrasound
- Cardiac Catheterization Laboratory

Each of these areas is staffed independently, although all service a common group of cardiologists. A further subdivision exists within the department of Electrocardiology insofar as separate patient files are maintained for the three diagnostic services provided: electrocardiograms (EKG), exercise testing, and 24-hour ambulatory monitoring (Holters). Departments are spread over several city blocks within the hospital site (Figure 1).

Prior to 1986, each department within the Division of Cardiology developed and maintained their administrative systems independently. However, it became increasingly apparent that the development of a system based on the commonalities between the departments would result in significant administrative benefits. If clinical data were also captured, such a system could also serve as a useful tool for enhancing the quality of patient care and for clinical research.

SYSTEM OVERVIEW

In early 1986, a development project was initiated to design and implement an integrated patient management system for all areas within the Division of Cardiology. It was determined that the system would have to satisfy general requirements as follows:

- A single database for all of the diagnostic areas would be the core module of the system.

- The system would serve both clinical and administrative needs.

- The system would be capable of capturing data through interfaces to clinical equipment wherever possible.

- Customized user interfaces would be provided in order to maximize efficiency and provide maximum data security. These interfaces should present the user with a menu containing only those functions authorized for his use.

Similar systems have been developed elsewhere [1]. Considerable work has been done on systems for cardiac Intensive Care Units [2,3] and for surgical follow-ups [4].

Inquiries directed to various vendors indicated that commercial packages would not provide the flexibility and comprehensiveness desired. Consequently, the development of the system in-house was undertaken. The Flagship Application Generator from EPIC Systems Corp. was selected as the development environment. This package currently runs under the MIIS operating system and is used (at VGH) on a Data General MV/10000.

The system went "live" for the Pacemaker Clinic on July 1, 1986. Functions to service the Cardiac Ultrasound and Electrocardiology departments were implemented on January 1, 1987. Originally, it was planned to develop an automated interface to the Cardiac Catheterization Laboratory's PC-based system and, in fact, that development had started. Because of difficulties with the PC-based system, the Catheterization Laboratory has recently decided to pursue development of modules similar to those used by the other departments.

SYSTEM FUNCTIONS

Major functions of the installed system include:

- Test orders are captured in an integrated manner; a single data entry function is used for all clinical procedures. However, the data entry clerks can enter information only for the type(s) of tests for which they have been authorized.

- Integrated functions for test results reporting permit simultaneous capture of clinical data to the database. The report generators make extensive use of user-defined codes which trigger the incorporation of pieces of predefined text into the report (Figures 2-3) [5].

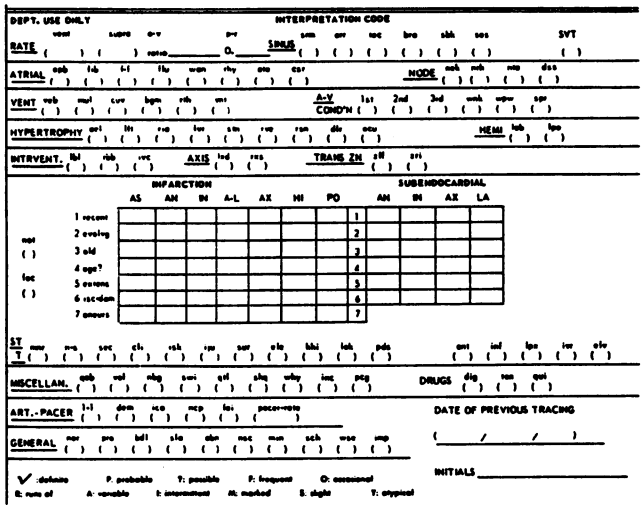


Figure 2. EKG Results Report Checklist

```
                                                        ECC  3 E
VANCOUVER GENERAL HOSPITAL                  MR.          000-00-00
                                            Public, John Q.
DIAGNOSTIC CARDIAC SERVICES                 Dr. NOSCOVICH, MICHAEL D
                                            20 May 19    Male    67

                    C L I N I C A L   I N F O R M A T I O N

DRUGS:  None given.
DIAGNOSIS/SYMPTOMS:  Chest pain
                     Old MI
SURGERY:  TBG
REASON FOR TEST:  Comparison
Taken on 28 Apr 87 at 11:06                 Technician:  MT
                                            This ECG No.:  82-04494-1

                    I N T E R P R E T A T I O N

Ventricular rate:  65
A-V ratio:  2:1
P-R interval:  0.102
Sinus tachycardia.
Two atrial ectopic beats.
Occasional atrial flutter.
Frequent unifocal ventricular ectopic beats.
Possible second degree A-V block.
Probable atrial enlargement.
Right bundle branch block.
Pattern of old anterior infarction.
Extension of possible inferior infarction.
ST/T abnormalities consistent with clinical diagnosis.
Prolonged QTc interval.
Abnormal ECG.
No significant change from previous tracing of 4 Mar 87 at 11:03 AM.
mk                                          C.V. Tomlinson, M.D.
```

Figure 3. EKG Automated Report

In addition to accelerating the data entry process, the previous transcription error rate of approximately 5% has been reduced to nearly zero through the use of context-sensitive validation routines for the codes. Figure 4 displays a portion of the ECHO report checklist screen.

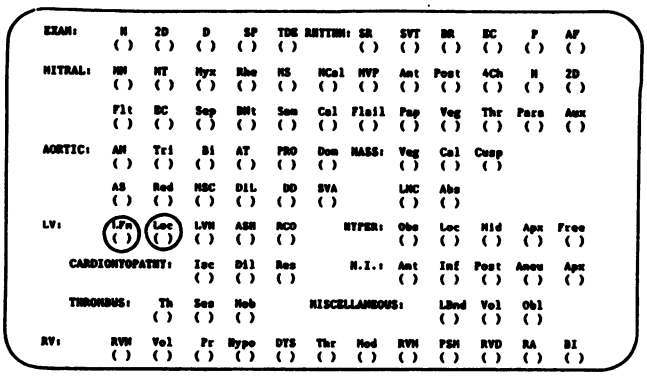
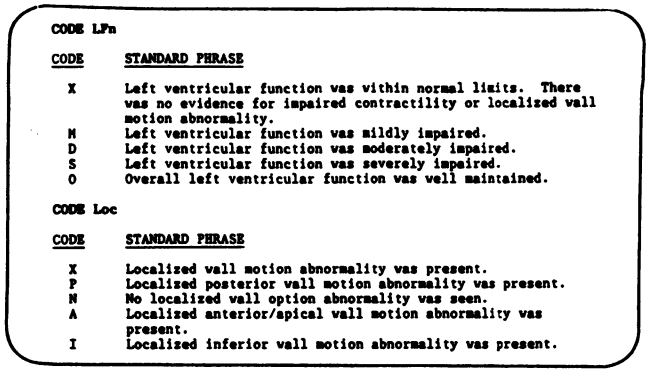


Figure 4. ECHO Codes Checklist Screen

Figure 5 lists the valid responses for the two circled items (LFn and Loc) in Figure 4.



CODE LFn

CODE	STANDARD PHRASE
X	Left ventricular function was within normal limits. There was no evidence for impaired contractility or localized wall motion abnormality.
M	Left ventricular function was mildly impaired.
D	Left ventricular function was moderately impaired.
S	Left ventricular function was severely impaired.
O	Overall left ventricular function was well maintained.

CODE Loc

CODE	STANDARD PHRASE
X	Localized wall motion abnormality was present.
P	Localized posterior wall motion abnormality was present.
N	No localized wall option abnormality was seen.
A	Localized anterior/apical wall motion abnormality was present.
I	Localized inferior wall motion abnormality was present.

Figure 5. Valid Entries for Codes LFn and Loc

Entry of an invalid response, specific to the item, will produce an audible alarm and a display of the valid responses at the bottom of the screen before the user is prompted again for an entry. Free test fields are always available to accommodate those cases where there is no suitable predefined code. Periodic reviews of the comments entered in these free text fields will assist in updating the code lists on an ongoing basis.

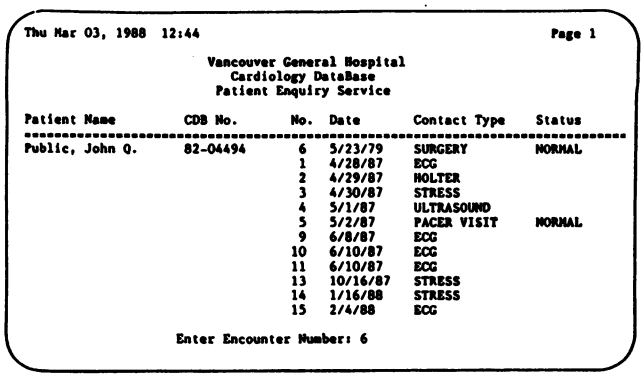
- An automated interface to the hospital's A/D/T system captures demographic data for new patients, thus speeding the data entry process and reducing the number of patient mis-identifications. The interface is triggered by entry of the patient's unit number (lifetime hospital ID number). The patient name registered in the A/D/T system against this number is displayed for confirmation. Should this name not be correct, the data entry clerk (after verifying correct entry of the unit number) would then contact the Admitting Department to resolve the conflict.

- An automated interface to the Billing/Accounts Receivable (B/AR) system transfers all applicable charges and supporting data. This function has greatly reduced the number of rejected billings by the incorporation of a number of data validity checks. The error rate prior to automation constituted approximately 3% of the total billed value. This error rate has been reduced to essentially zero.

- A transaction logging function transfers the details of every transaction (date and time stamped) to a separate processor. This permits full recovery of the database to the last transaction in the event of a major hardware or software failure. While logging to another disk (or tape) on the same processor would provide some measure of protection, the network environment at VGH facilitates the added protection afforded by using a separate processor.

- All of the required management and workload reports are generated automatically. This is another by-product of the data capture during order entry and test result reporting.

- A "layered" inquiry function permits cardiologists to view patient data to any of several levels of detail, from a summary of contacts with the system to specific clinical findings (Figures 6-7).



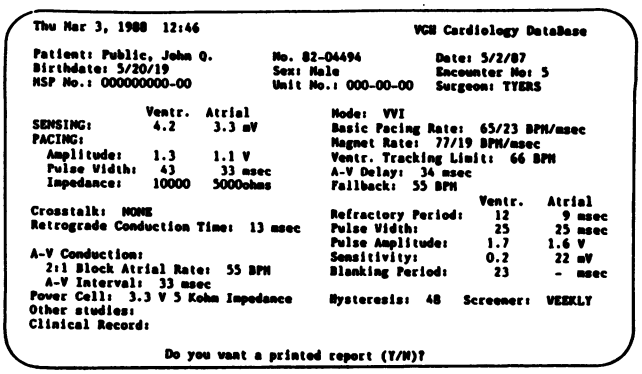
Thu Mar 03, 1988 12:44 Page 1

Vancouver General Hospital
Cardiology DataBase
Patient Enquiry Service

Patient Name	CDB No.	No.	Date	Contact Type	Status
Public, John Q.	82-04494	6	5/23/79	SURGERY	NORMAL
		1	4/28/87	ECG	
		2	4/29/87	HOLTER	
		3	4/30/87	STRESS	
		4	5/1/87	ULTRASOUND	
		5	5/2/87	PACER VISIT	NORMAL
		9	6/8/87	ECG	
		10	6/10/87	ECG	
		11	6/10/87	ECG	
		13	10/16/87	STRESS	
		14	1/16/88	STRESS	
		15	2/4/88	ECG	

Enter Encounter Number: 6

Figure 6. Patient Inquiry Selection Screen



Thu Mar 3, 1988 12:46 VGH Cardiology DataBase

Patient: Public, John Q. No. 82-04494 Date: 5/2/87
Birthdate: 5/20/19 Sex: Male Encounter No: 5
HSP No.: 000000000-00 Unit No.: 000-00-00 Surgeon: TYERS

	Ventr.	Atrial
SENSING:	4.2	3.3 mV
PACING:		
Amplitude:	1.3	1.1 V
Pulse Width:	43	33 msec
Impedance:	10000	5000ohms

Mode: VVI
Basic Pacing Rate: 65/23 BPM/msec
Magnet Rate: 77/19 BPM/msec
Ventr. Tracking Limit: 66 BPM
A-V Delay: 34 msec
Fallback: 55 BPM

	Ventr.	Atrial
Refractory Period:	12	9 msec
Pulse Width:	25	25 msec
Pulse Amplitude:	1.7	1.6 V
Sensitivity:	0.2	22 mV
Blanking Period:	23	- msec

Crosstalk: NONE
Retrograde Conduction Time: 13 msec
A-V Conduction:
2:1 Block Atrial Rate: 55 BPM
A-V Interval: 33 msec
Power Cell: 3.3 V 5 Kohm Impedance
Other studies:
Clinical Record:
Hysteresis: 48 Screener: WEEKLY

Do you want a printed report (Y/N)?

Figure 7. Pacemaker Clinic Visit Data Screen

TECHNICAL DESIGN

The database itself was constructed using the Flagship Application Generator from EPIC Systems Corp., a very powerful and very flexible dictionary-driven database package, written in the MIIS programming language. It provides a number of "windows" where calls to customized MIIS modules can be inserted.

Each user is assigned an individual menu of specific functions relevant to his requirements. For example, EKG clerks can select the EKG report generator from their main menu without the need of passing through a generic "Report Generator" submenu. The EKG clerk menu will not have the ECHO report generator selection but the menu for a relief clerk (who might work in both departments) would have both selections available.

The host computer is a Data General MV/10000 with 4 MBytes of memory and twin 592 MByte disk drives. MIIS runs in native mode and, therefore, serves as its own operating system. This system is connected, via the LAN, to other similar computers which support the A/D/T and B/AR systems, as well as the transaction logger function.

Each patient "encounter" (defined as any diagnostic test, visit, etc.) is uniquely identified in the system by the combination of the patient's ID number and an encounter code number. Both of these identifiers are assigned by the system.

The report generators were developed in-house as collections of MIIS modules interfaced into the Flagship database structure. They utilize full-screen data entry menus which mimic as closely as possible the reporting forms used by the physicians (Figures 2, 8-10). Similar data entry forms are currently under development for the Cardiac Catheterization Laboratory and for Cardiac Surgery. These will also enable automatic generation of the operative reports while capturing the clinical data into the database.

```
DRUGS:
        Digitalis:  ( )      Quinidine   ( )      B-blocker   ( )
        Other:

DIAGNOSIS/SYMPTOMS:
        Chest pain  (X)      Myo. Isc.   ( )      ?MI         ( )
        Known MI    ( )      Old MI      (X)      Ht. Failure ( )
        Dysrhythmia ( )      Lung Dis.   ( )
        Valve Dis.:
        Other:

SURGERY:
        Pre-op.     ( )      Post-op.    ( )      Pacemaker   ( )
        Non-cardiac:
        Cardiac:    TBG

REASON FOR TEST:
        Diagnosis   ( )      Comparison  (X)      Screening   ( )
```

Figure 8. EKG Report Generator: Clinical Information Screen

The combination of available MIIS "windows" in the database package and the ability to provide RS-232 standard ports virtually anywhere in the hospital (due to the flexibility of the hospital's LAN) will greatly facilitate the development of direct interfaces to clinical devices as they are needed.

```
RATE:
     Vent. 65      Supra              A-V ratio 2:1     P-R: 0.102

SINUS:
       srm  arr  tac  bra  sbk  sas       SVT
       ( )  ( )  (X)  ( )  ( )  ( )       ( )

ATRIAL:                                              NODE:
       apb  fib  f-f  flu  van  rhy  ata  csr        nek  nrh  nta  dss
       (2)  ( )  ( )  (0)  ( )  ( )  ( )  ( )        ( )  ( )  ( )  ( )

VENT.:                                    A-V COND'N:
       veb  mul  cuv  bgm  rth  vnt             1st  2nd  3rd  vnk  vpv  spr
       (F)  ( )  ( )  ( )  ( )  ( )             ( )  (?)  ( )  ( )  ( )  ( )

HYPERTROPHY:                                         HEMI:
       ael  lft  ria  lvr  stn  rve  rsn  dlr  acu        lab  lpo
       (F)  ( )  ( )  ( )  ( )  ( )  ( )  ( )  ( )        ( )  ( )

INTRVENT:                 AXIS:                 TRANS ZN:
       lbl  rbb  ivc            lxd  rxs                 zlf  zri
       ( )  (X)  ( )            ( )  ( )                 ( )  ( )
```

Figure 9. EKG Report Generator: Diagnostic Comments I

```
                          INFARCTION                          SUBENDOCARDIAL
                    AS   AN   IN  A-L   AX   HI   PO        AN   IN   AX   LA
       1 recent     ( )  ( )  ( )  ( )  ( )  ( )  ( )  1    ( )  ( )  ( )  ( )
not    2 evolvg     ( )  ( )  ( )  ( )  ( )  ( )  ( )  2    ( )  ( )  ( )  ( )
( )    3 old        ( )  (X)  ( )  ( )  ( )  ( )  ( )  3    ( )  ( )  ( )  ( )
       4 age?       ( )  ( )  ( )  ( )  ( )  ( )  ( )  4    ( )  ( )  ( )  ( )
foc    5 extens     ( )  ( )  (?)  ( )  ( )  ( )  ( )  5    ( )  ( )  ( )  ( )
( )    6 isc-dam    ( )  ( )  ( )  ( )  ( )  ( )  ( )  6    ( )  ( )  ( )  ( )
       7 aneurs     ( )  ( )  ( )  ( )  ( )  ( )  ( )  7

ST/T: ( )
 nnr  n-s  sec  cli  isk  iju  sur  ele  khi  lok  pds  ant  inf  lpx  ivr  elv
 ( )  ( )  ( )  (X)  ( )  ( )  ( )  ( )  ( )  ( )  ( )  ( )  ( )  ( )  ( )  ( )

MISCELLANEOUS:                                              DRUGS:
 qab  vol  nbg  swi  qtl  shq  vhy  inc  pcg                 dig  tox  qui
 ( )  ( )  ( )  ( )  (X)  ( )  ( )  ( )  ( )                 ( )  ( )  ( )

ART.-PACER:      1-1  dem  ica  ncp  fai  avs  pacer-rate
                 ( )  ( )  ( )  ( )  ( )  ( )

GENERAL:   nor  pro  bdl  sla  abn  nsc  nin  sch  vse  imp
           ( )  ( )  ( )  ( )  (X)  (X)  ( )  ( )  ( )  ( )
```

Figure 10. EKG Report Generator: Diagnostic Comments II

IMPLEMENTATION

Conversion to the new system presented several significant problems. Over 41,000 patient records are currently on file, organized in different ways in different departments. Because little clinical data were available in a machine readable form, the decision was reached to pre-load the new system only with patient demographic data. In addition, the patients' file numbers in the old systems were also loaded into the new system as cross-references to the new system's patient IDs. Note that, since each diagnostic center kept independent file systems, a patient could have as many as four "old" ID numbers loaded into the new system. During order entry the system checks to see if the patient just entered had an encounter of the same type in one of the old systems. If so, the system displays the old file number to the clerk and then deletes it from the patient's record. This facilitates the reorganization of the departmental files to conform to the new system. A Patient Merge function allows patients with different ID numbers in different departments to be assigned a common number in the new system.

SYSTEM BENEFITS

Introduction of the Integrated Cardiology Patient Management System has resulted in a number of sub-

stantial benefits to the hospital and the Division of Cardiology:

- Staff productivity has markedly increased by the streamlining of the order entry and test result reporting functions. Prior to introduction of the system, a 48 to 72 hour EKG "turnaround" time (elapsed time for return of the EKG report to the patient's chart on the ward) was the norm. This has been reduced to slightly less than 24 hours. At the same time, staff levels have decreased by approximately 10% with a constant or slightly increasing number of tests requested. Faster retrieval of patient files has resulted from introduction of the common patient identifier. In addition, whereas formerly medical stenographers were required to transcribe the test reports, data from the checklists can be entered by ordinary clerks.

- The accuracy and comprehensiveness of the billing and management reporting functions have improved markedly. The considerable amount of staff time (approximately 0.25% of a full-time employee) previously required for these functions has been reduced to nearly zero.

- Patient recalls and follow-ups have been simplified by eliminating many of the manual procedures used previously.

- Accumulation of integrated clinical data over an extended period of time will provide a valuable tool for research and eductional programs.

- The database resulting from the integrated approach has proven to be easier to maintain and functionally expand.

FUTURE DIRECTIONS

Acceptance of the integrated system by departmental staff has been very encouraging. Consideration is currently being given to further expansion of the system's functionality. This expansion might encompass some of the following directions:

- Capture of detailed clinical data. At the present time information is captured at the level of detail contained in reports. Future system development will concentrate on extending the level to include, for example, the automated storage and online retrieval of EKG tracings.

- Introduction of optical mark reader technology. Many of the test results are currently reported using checklists which are reproduced on the data entry screen so that the clerk can transcribe the data into the system. Development of a machine readable checklist, similar to those described by Williams et al. [6] will improve the data entry speed and eliminate transcription errors.

- Inclusion of Cardiac Surgery. Capture of data related to cardiac surgical procedures and generation of the surgical reports is currently under development. This module will also provide detailed management statistics and costs data.

CONCLUSION

The Integrated Cardiology Patient Management System is providing significant medical and administrative benefits by providing a uniform and efficient approach to the processing of data from the various treatment centers within the Division of Cardiology.

Medical benefits are derived from the system's ability to provide a unified, concise source of information about a patient's contacts with the Division. The information is available at several levels of detail, thereby allowing the staff member to view only as much information as he requires.

Integration of the various functions has allowed the hospital to provide increased services while simultaneously reducing operating expenses. Staff are able to generate reports and respond to queries more quickly by using common procedures. Managers now receive a more comprehensive view of the Division's operations. File management procedures have been improved due to the introduction of an integrated patient identifier.

The ongoing capture of clinical data will expand the database so that it will serve as an effective platform for research and education programs, consistent with the goals of a teaching hospital.

Very supportive response to the integrated system has encouraged continued development. Expansion into related areas and increased functionality will provide further benefits to the hospital.

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